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ABSTRACT

This bulletin discusses the concept of technology and the nature of technology education in Australia, including: technological literacy, technological awareness, technological capability, and information technology. Recent curriculum developments in technology and what they mean for teachers' roles in mathematics and science are explored. In order to help teachers develop lessons that take into account students' views, three methods that teachers could use to find out what their students think about technology are explained. These are: writing an essay; responding to a survey; and drawing a picture. A reproducible copy of a technology questionnaire is included. (MKR)

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What Research Says to the Science and Mathematics Teacher

National Key Centre for School Science and Mathematics Number 10

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TECHNOLOGY EDUCATION IN SCIENCE AND MATHEMATICS

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THERE ARE many ways to think about technology. People think about it in ways that fit their circumstances and experiences. In response to a request to define technology, one science teacher wrote:

> Technology is the 'applied knowledge' of science. Technology minus 'science' does not exist. Therefore technology may be defined as the practical off-shoot of science.

The theme 'technology as applied science' was a popular one among 94 Australian science teachers who were asked to respond to this question (Rennie, 1987). That's not surprising – they were, first and foremost, science teachers! Here's what another teacher wrote in answer to the same question:

> Technology is the development of instruments useful in simplifying mathematical calculations and processes after appropriate algorithms have been fed into the instrument.

You might not be surprised to learn that this definition came from a mathematics teacher or that, when mathematics teachers wrote about equipment in technology, they usually mentioned computers and calculators.

But these aren't the only kinds of things which teachers write about technology. Artefacts, procedures to make work easier and interaction with society are also mentioned. Below are two more examples, the first from a mathematics teacher, and the second from a science teacher:

> Technology includes the artefacts/implements/instruments/procedures developed/invented by a community/society in order to advance itself culturally/professionally and to improve its living standards.

> A culture-bound phenomenon which makes tasks easier. Technology incorporates a range of tools from the very simple to the very complex.

Students have different ideas about technology, too. They mostly agree that it is important, but many don't realise how diverse and pervasive it is. Some think of technology in terms of computers, some in terms of environmental disaster. Others think about inventing, manufacturing and progress with positive and negative consequences (Rennie & Sillitto, 1988).

Technology has become part of the curriculum in Australia and what science and mathematics teachers and their students think about technology has become very important. Teachers of subjects like technical drawing, home economics and manual arts

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often have been assumed to be the technology specialists. Now it seems that teachers in other subjects, like mathematics and science, have an increasingly important role to play. What does this mean for science and mathematics teachers? What will they have to know? What will they have to do? Developments all over the world indicate that teachers need to understand technology as a whole curriculum theme, not just as it relates to mathematics or science. At the same time, the special relationship between technology and their own subject needs to be examined. Further, teachers need to consider children's ideas and how they think about technology, because whatever happens in the classroom will be shaped not only by what teachers do but by what students think.

In this issue of *What Research Says ...*, we explore the concept of technology and the nature of technology education. We look at recent curriculum developments in technology and what they mean for teachers of mathematics and science. So that they can develop lessons which take account of students' views, we describe three methods which teachers could use to find out what their students think about technology.

WHAT IS TECHNOLOGY?

GARDNER, PENNA AND BRASS (1990) analysed a number of descriptions of technology from the literature associated with curriculum development. They identified six recurring elements: technology is concerned with *people* (a human endeavour); *purposes* (satisfaction of human needs or wants); *resources* (materials, energy, capital, time); *tools and machines* (to extend capabilities); *processes* (storing, transforming, transporting); and *products* (artefacts). They also emphasised the technological process, listing *invention* (of a new idea), *refinement* (of the invention), *innovation* (making it available to the public), *diffusion* (the uptake of the innovation) and *transfer* (to a new society or country).

It is clear that technology involves both products and processes, including designing, producing, refining and marketing. All of this occurs in a social context. If we understand technology in this broad way, how does it help us to understand what technology education might be, especially as it affects science and mathematics teachers?

WHAT IS TECHNOLOGY EDUCATION?

TECHNOLOGY EDUCATION is much older in the UK than in Australia, and developments here have been informed by the UK experience. The Association for Science Education (ASE) set up a working party to explore science curricula and technology in the UK. It commented on the inadequacies of ad hoc developments, such as approaches dominated by craft teachers, 'hi-tech' courses focusing on computers and electronics, pre-engineering courses, or science courses with an applied science component. The ASE report (Woolnough, 1988) identified four components to technology education:

- technological literacy, in which students become familiar with the content and methodologies of a range of different technologies;
- technological awareness, in which students are made aware of personal, moral, social, environmental and economic implications of technology;
- technological capability, in which students tackle a variety of technological problems considering a range of perspectives;
- information technology, in which students obtain, handle and communicate information.

These four components have implications for how technology might be incorporated into the curriculum. In the UK, *Technology* was first introduced in 1990 as one of the 10 curriculum subjects of the National

Curriculum for pupils aged 5-16 years. The curriculum structure has emphasised technological capability and information technology, although technological awareness and literacy also play a role. However, according to an HMI report, teachers have found problems in interpreting and implementing the requirements of the curriculum and it is now under revision.

Do our mathematics and science courses develop technological awareness, literacy and capability?

What kinds of curriculum decisions are being made in Australia? The Australian Education Council has proposed that all States include technology as a separate curriculum strand. There is a national curriculum statement about technology education which has not been released yet. Independently, several Australian States have included *Technology* in recent curriculum statements. In Western Australia, *Science and Technology* (which includes computer studies) has formed one of seven components of the K-10 curriculum from 1985. One school has integrated its technology program across the curriculum, and tied it in with the four ASE components (Treagust & Mather, 1990). Another curriculum project has emphasised technological capability, resulting in a textbook for teachers of Years 5 to 8 (Treagust, Kinnear & Rennie, 1991). Students work on design projects related to leisure, toys and the zoo.

Technology is included in the New South Wales Statement of Curriculum as part of the *Technological and Applied Studies* Key Learning Area in secondary schools. In primary schools, technology is linked with science. The *Technology Studies* subject introduced in 1990 in schools in New South Wales has two strands, one focusing on computer software applications and the other on technology studies. In the latter strand, students are expected to learn about technology, to use technologies and to design, research and assemble a project. Such a program reflects the four components of technology outlined by the ASE.

In Victoria, *Technology Studies* is one of the P-10 Curriculum Frameworks and has the subtitle *Thinking, Making, Doing* (Ministry of Education, Victoria, 1988). The curriculum also emphasises technological capability with its strong bias to the technological process (inventing, planning, evaluating) and student outcomes are defined in terms of knowledge and skills relating to technology, the understanding and use of the technological process, technology and society, and personal development.

WHAT IS THE ROLE OF SCIENCE AND MATHEMATICS TEACHERS?

IN MAY 1990, the second meeting of the Prime Minister's Science Council was devoted to 'Science and Mathematics in the Formative Years' and included discussion of curricula, teachers and learners. In his comments on this topic, Fensham states:

> I suspect the various concerns about mathematics and science education in Australia ... could be well summarised as a wish for a *'practical capability'* in our students in mathematics and science that will enable them *to think, live, and to act in the technological world we have chosen for them.* (Fensham, 1990a, p. 138)

The implication is that quality learning in mathematics and science will produce citizens who are confident and capable, people who can think and act in a socially responsible way. Fensham (1990b) examines the ability of our present science courses to prepare students in the three areas of technological awareness, literacy and capability. Changes in science education have moved towards making students aware of technology, but only by presenting it as applications of science. In contrast, some science courses, notably the Salter courses in the UK, start from technological issues or from where technology impinges on the lives of young people. Such courses are more

likely to develop technological awareness and literacy together with a sense of confidence and social responsibility. Fensham questions whether Australia's science courses in their present form can develop technological capability. His paper makes interesting reading for teachers willing to think critically about the science content of our curricula.

Even if new science and mathematics courses are developed which will encourage technological capability in our students, whether they develop technological literacy, the confidence to deal with technology in a socially responsible way, remains to be seen. Experience elsewhere suggests we should look carefully at the outcomes.

An example comes from a large London comprehensive secondary school. Here, the students who had followed a three-year technology course (during Years 7-9) were asked to complete one of the following sentences:

> It is important for me to know about science and technology because ...
>
> It is not important for me to know about science and technology because ...

Most students completed the first sentence. Their reasons fell into three categories: competency – do-it-yourself construction and repair jobs (girls and boys equally made this response); careers – to help you get a job (boys more than girls gave this response); and interpretive – to help you to live with confidence in the world (responses of this kind were almost three times as likely to come from girls as from boys) (Grant & Harding, 1987). There is no doubt that students learned from the course, but their learning outcomes were presented differently. The boys were focusing more on technological capability (the doing of technology) and the girls on technological literacy.

The importance of values and social responsibility cannot be overlooked. Our science and mathematics courses are heavily weighted towards knowledge, in spite of recent curriculum projects which have emphasised process or skills. Technology courses have emphasised skills, with a shift from craft skills to those of problem solving. Neither has included a strong values component. Importantly, several studies have shown that girls are more likely to be motivated to study science and technology when a consideration of values is integrated within the course (Grant & Harding, 1987). A technology course which emphasises values could encourage not only more equitable participation, but also provide a vehicle for technological critique and the consideration of social responsibility.

The importance of values and social responsibility cannot be overlooked.

The need for a social and critical aspect in technology education in Australia is clear. Eckersley (1987) reported to the Commission for the Future on the attitudes of Australian people to science and technology. He concluded that "Australians applaud technological progress, and fear it" (p. 1). Nuclear weapons, pollution and computers "appear to be a major source of the pessimism many Australians feel about the future" (p. 3). He notes that many teenagers could not imagine a peaceful and desirable future.

Teachers, including mathematics and science teachers, share a responsibility to help students cope with our technological world. It also makes it very important to understand what our students think about technology and its relationship to them.

WHAT DO YOUR STUDENTS THINK ABOUT TECHNOLOGY?

WHAT STUDENTS learn in your classroom depends not only on what you plan for them to learn, but on the knowledge and understandings which they bring to the topic. What goes on in their heads is shaped by what is already there. If you can find out

SUPPLEMENT

TECHNOLOGY QUESTIONNAIRE

Name _____ School _____ Class _____

Here are some questions for you. For each question, circle the number which is the right answer for you.

Part A: What is technology?

	STRONGLY AGREE	AGREE	CAN'T DECIDE	DISAGREE	STRONGLY DISAGREE
1. Technology mainly concerns computers and similar equipment.	1	2	3	4	5
2. Making models and testing them is part of technology.	1	2	3	4	5
3. Technological appliances can only be used by qualified people.	1	2	3	4	5
4. Working with materials is an important part of technology.	1	2	3	4	5
5. Without electricity, there would be no technology.	1	2	3	4	5
6. Technology involves designing solutions to problems.	1	2	3	4	5
7. Most people have little to do with technology in their everyday lives.	1	2	3	4	5
8. In technology there are opportunities to design new products.	1	2	3	4	5
9. Two hundred years ago there was no technology.	1	2	3	4	5
10. Technology means inventing new ways of doing things.	1	2	3	4	5

Part B: What do you think about technology?

	STRONGLY AGREE	AGREE	CAN'T DECIDE	DISAGREE	STRONGLY DISAGREE
1. I am interested in technology.	1	2	3	4	5
2. Technology makes the world a better place to live in.	1	2	3	4	5
3. I would like to learn more about technology.	1	2	3	4	5
4. Technology has brought more good things than bad things.	1	2	3	4	5
5. I would like a career in technology later on.	1	2	3	4	5
6. It is worth spending money on technology.	1	2	3	4	5
7 I like to read books and magazines about technology.	1	2	3	4	5
8. Inventions in technology are doing more good than harm.	1	2	3	4	5
9. I would like to join a hobby club about technology.	1	2	3	4	5
10. Technology is needed by everybody.	1	2	3	4	5

This page is a supplement to a publication entitled *Technology Education in Science and Mathematics* authored by Jan Harding and Léonie Rennie and published by the Key Centre for School Science and Mathematics at Curtin University of Technology, Perth, Australia.

WHAT TECHNOLOGY MEANS TO ME

Name _____ School _____ Class _____

Technology can mean different things to different people. When you read the word 'technology' what comes into your mind? What does technology involve?

Please tell us what technology means to you by writing about it, or by drawing a picture. You might like to do both.

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your students' current thinking and understanding of technology, you will know where to start. You'll be in a position to help students challenge their ideas, if that is appropriate, and offer opportunities for them to develop their understanding.

Here are descriptions of three ways of obtaining information about students' perceptions of technology: writing an essay; responding to a survey; and drawing a picture. The different methods give different information and each has some advantages and limitations.

Writing about Technology

Give each student a piece of paper containing the following essay topic, and ask them to write at least three sentences:

> Technology can mean different things to different people. When you read the word 'technology' what comes into your mind? What does technology involve?

Ten minutes seems to be an adequate amount of time to give students to write about this topic. If you want longer essays, you can give more time.

You'll find that the essays from your class will make interesting reading. There might be a local issue upon which your students could comment, but probably you will find a wide range of responses. Some will make good discussion topics, or perhaps you could get groups of students in the class to use their essays and come to a consensus definition for technology.

Rennie and Sillitto (1988) collected 212 essays on the above topic from 13-year-old students in Western Australia. They found a large variation in how much students wrote, and what they wrote about. Overall, students wrote about technology in terms of: its products, like computers and machines; its processes, like invention and manufacturing; and its social aspects, like good and bad consequences.

The content of these Western Australian essays was very similar to that written in other countries. The technology essay topic was prepared by a team of researchers led by Jan Raat and Marc de Vries from Eindhoven, The Netherlands. Their project, called *Pupils' Attitudes Towards Technology (PATT)*, coordinated the collection of data relating to students' attitudes and knowledge about technology in many countries in the world.

Responding to a Questionnaire

The PATT project also developed very comprehensive attitude questionnaires about technology, including questionnaires about interest, gender-role pattern, consequences, difficulty and careers in technology. Some of these have been adapted for use in schools in Western Australia (Rennie & Treagust, 1989).

A supplement to this document has two short questionnaires about technology. *Part A – What is Technology?* asks students questions about the nature of technology. The five odd-numbered statements investigate the breadth of students' understanding of technology. 'Agree' responses indicate a narrow perspective. The five even-numbered statements assess students' understanding of technology as a design process – the thinking-making-doing concept of technology. 'Agree' responses indicate agreement with this perspective.

Part B – What Do You Think About Technology? concerns students' attitudes about technology. For the five odd-numbered statements, 'Agree' responses indicate that students have a positive interest in technology. The even-numbered statements refer to the social implications of technology. 'Agree' responses indicate that students' perceive technology to have favourable consequences. 'Disagree' responses indicate that students perceive technology in a negative way.

Photocopy the page in the supplement if you would like your students to respond to these items. All of the items have been used before, and the four kinds of items form four

subscales to do with the diversity of technology (Part A, odd-numbered items), technology as a design process (Part A, even-numbered items), students' interest (Part B, odd-numbered items) and perceptions about the social implications of technology (Part B, even-numbered items).

Your students' perceptions of technology ... different methods give different information.

If you use the questionnaire to find out about students' perceptions of technology, there's no need to work out scores on subscales. It's probably more informative just to get a picture of the pattern of responses for each of the items. This will give you a starting point for future discussions or lessons about technology. If you did want to use subscales to make comparisons between classes, for example, just add up the scores on each item of the subscale.

Many students, particularly girls, respond in the middle category on items like these, particularly those about the social aspects of technology. Grant and Harding (1987) investigated further why so many students chose in this category, and concluded that they often suspend judgement – the decision to agree or disagree depends on the circumstances. The items just didn't have enough information for these students to decide which aspects of technology were referred to. Class discussion of some of the issues has led to lively debate.

Drawing a Picture about Technology

A third way to find out what students think about technology is to ask them to draw a picture about 'what technology means to me'. This is good fun for upper primary and lower secondary classes, and many students will draw clever and interesting cartoon figures and situations. Often they need to be interpreted 'tongue-in-cheek'.

This is a similar technique to the Draw-a-Scientist task which appeared in *What Research Says... No. 4* (Kahle, 1990). But be careful about how you phrase the instructions for the drawing! 'Draw a technologist' or 'draw a person involved in technology' will probably give you quite a different picture. Be clear what you want to find out, then give the instructions. A sample set of instructions is contained in the supplement, combined with the essay question. Some students might complain that they can't draw, but this doesn't matter – stick figures, outlines and labels will help to overcome any lack of artistic skills.

Sit down and think about the drawings you get. You might want to sort them into groups which represent particular perceptions of technology. For example, some might focus on machinery, others might involve advances in medicine. Space travel is a popular theme. People who have used drawings as a way of getting at students' ideas have found that some drawings can express strong emotions representing fear of technological appliances, like computers, and concern for the future of our planet and ourselves.

Which Method Works Best?

Choosing the best method of finding out what students think about technology depends on what you want to know. Essays give students the opportunity to write about what *they* think is important but, if a particular aspect of technology isn't mentioned, you can't assume that they don't know about it. Drawings also give students free reign, and can elicit strongly positive or negative attitudes which students might not want to write in an essay. Essays are more likely to stick to ideas and 'facts'. The age of the student is also important in deciding whether to use an essay, a drawing or both.

If you want all students to give their ideas about the *same* aspects of technology, a questionnaire might be useful. Instead of using the items given here, you could make up your own. It is a bit more time-consuming (and not as much fun) to count responses on

questionnaires than to read essays or look at drawings, but the information can be very helpful. And there are ways to make the counting easier – for example, shuffle then redistribute the unnamed questionnaires to students and use a show of hands to get the number choosing each response category for each question.

CONCLUSION

WE BEGAN by discussing technology and technology education. Current thinking about technology education suggests that there are four aspects to be considered: technological literacy, technological awareness, technological capability and information technology. Assisting students to achieve technological capability appears to be an important challenge for science and mathematics teachers. It is also clear that technological literacy must be included in a technology course if students are to develop a sense of social responsibility and confidence as users of technology.

How technology education will affect science and mathematics curricula in Australia is still being decided. However, teachers' own views of technology and the views of their students will play a crucial role in determining the outcomes of those courses. We have described three methods which teachers could use to find out their students' ideas about technology so that those ideas can be built into whatever course is offered. Whatever turns out to be the formal role of mathematics and science teachers in technology education, it is sure to be one of considerable influence on the future of our students.

REFERENCES

Eckersley, R. (1987). *Australian attitudes to science and technology and the future* (A report for the Commission of the Future). Carlton, Vic: Australian Government Printing Service.

Fensham, P. J. (1990a). Response to curricula, learners and teachers. In S. Willis (Ed.), *Science and mathematics in the formative years* (pp. 135-146) (Papers for the Prime Minister's Science Council). Canberra: Australian Government Printing Service.

Fensham, P. J. (1990b). What will science do about technology? *The Australian Science Teachers' Journal, 36*(3), 8-21.

Gardner, P. L., Penna, C., & Brass, K. (1990). Technology and science: Meanings and educational implications. *The Australian Science Teachers' Journal, 36*(3), 22-28.

Grant, M., & Harding, J. (1987). Changing the polarity. *International Journal of Science Education, 9*, 335-342.

Kahle, J. (1990). *Images of scientists: Gender issues in science classrooms* (What Research Says to the Science and Mathematics Teacher No. 4). Perth, WA: Key Centre for School Science and Mathematics, Curtin University of Technology.

Ministry of Education (Schools Division) Victoria (1988). *The technology studies framework P-10*. Melbourne, Vic: Ministry of Education (Schools Division).

Rennie, L. J. (1987). Teachers' and pupils' perceptions of technology and the implications for curriculum. *Research in Science and Technology Education, 5*, 121-134.

Rennie, L. J., & Sillitto, F. J. (1988). The meaning of technology: Perceptions from the essays of Year 8 students. *The Australian Science Teachers' Journal, 34*(4), 68-76.

Rennie, L. J., & Treagust, D. F. (1989). Measuring students' attitudes and perceptions about technology: A multidimensional concept. *Research in Science Education, 19*, 221-230.

Treagust, D. F., Kinnear, A., & Rennie, L. J. (1991). *Teaching technology as a design process*. Perth, WA: Science Teachers' Association of Western Australia.

Treagust, D. F., & Mather, S. H. (1990). One school's approach to technology education: Integration across the curriculum. *The Australian Science Teachers' Journal, 36*(3), 50-60.

Woolnough, B. E. (Chairman) (1988). *Technological education and science in schools* (Report of the Science and Technology Sub-committee for the Association of Science Education). Hatfield, Herts: Association for Science Education.

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